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Effect of intercropping normal-leafed or semi-leafless winter peas and triticale after shallow and deep ploughing on agronomic performance, grain quality and succeeding winter wheat yield

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ABSTRACT

Winter peas (*Pisum sativum* L.) are a promising alternative to spring peas in organic farming. Intercropping winter peas and cereals may be a beneficial way to improve lodging resistance in normal-leafed and weed suppression in semi-leafless winter peas. At the same time, there is an increasing interest in a reduction in tillage intensity, e.g. shallow ploughing. A normal-leafed, coloured-flowered (cv. E.F.B. 33) and a semi-leafless, white-flowered winter pea (cv. James) were cultivated as sole crops or in intercrops with triticale (*Triticosecale* Wittmarck) on a loam soil under Northern German conditions during two seasons (2009/2010, 2010/2011) and compared for winter survival, lodging resistance, yield performance, grain quality and succeeding winter wheat yield. The two ploughing depths were short-term shallow ploughing to 10–12 cm and continuous deep ploughing to 25–27 cm. Intercropping did not improve winter survival, which depended on pre-winter development. Owing to the low lodging resistance of normal-leafed winter pea E.F.B. 33, sole cropping is not advisable. Intercropping normal-leafed winter pea E.F.B. 33 and triticale resulted in a better yield performance (2.54–3.39 t d.m. ha^{-1}) than the semi-leafless winter pea James sole (0.97–1.79 t d.m. ha^{-1}) or intercrops (2.05–2.86 t d.m. ha^{-1}). E.F.B. 33 had significantly higher grain crude protein, crude fibre and macronutrient contents, whereas the crude fat, starch and sugar content as well as the energetic feed value were higher in James. Wheat yields after E.F.B. 33 sole and intercrops were higher than after the corresponding James sole or intercrops. The biomass production, yield performance and the energetic feed value of winter pea sole and intercrops were comparable between ploughing depths or higher after shallow ploughing. Thus, E.F.B. 33-triticale intercrops provided better results than James sole or intercrops, except for the energetic feed value, and shallow ploughing was a good alternative to deep ploughing for the cultivation of winter peas.

1. Introduction

Agronomic problems in organic spring pea (*Pisum sativum* L.) cultivation, e.g., diseases, pests and yield instability have increased the interest in winter peas in Northern Germany. Winter peas are advantageous to spring peas in particular concerning the N_2-fixing capacity (Urbatzka et al., 2011b), the yield performance (Chen et al., 2006) and the yield stability (Urbatzka et al., 2011a) provided that winter survival is good.

The weak weed suppressive ability of semi-leafless winter peas as well as the low lodging resistance of normal-leafed cultivars may result in difficulties with yield formation or harvesting of sole crops. Intercropping peas and cereals reduces the infestation with weeds (Begna et al., 2011; Corre-Hellou et al., 2011; Hauggaard-Nielsen et al., 2001) and prevents peas from lodging (Kontturi et al., 2011; Urbatzka et al., 2011a). For these reasons, intercropping semi-leafless or normal-leafed winter peas and cereals would be one possible solution to ensure improved weed control, good canopy aeration and light interception, and to facilitate harvest operations and thus to avoid yield losses.

Despite long-term breeding programs in Western Europe, adequate winter hardiness of winter peas is still problematic (Bourion et al., 2003). Urbatzka et al. (2012) concluded that intercropping of winter peas and cereals can be effective in protecting cultivars with inadequate winter hardiness against frost when

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sowing is performed late in autumn. Growing winter peas in an intercrop with cereals may, as well, help trap drifting snow and therefore prevent exposure to cold temperatures and increase frost resistance, which is of particular importance for the windy weather conditions at the coastal areas in Northern Germany.

Inversion tillage is necessary to tackle weed control in organic farming. A decrease of the ploughing depth, however, reduces the fuel consumption and the soil carbon dioxide loss (Plouffe et al., 1995; Reicosky and Archer, 2007). On account of the fact that organic farming is targeted at reducing the impact of human activities on the environment, a reduction of the ploughing depth is more consistent with the aims of organic farming. Nonetheless, the agronomic suitability of shallow ploughing has to be examined in detail. Owing to their importance in organic crop rotations, especially in stockless organic farming systems, the primary focus should be on the agronomic performance of grain legumes. Moreover, grain legumes are considered more sensitive to non-optimal soil conditions than other crops, e.g., cereals (Jayasundara et al., 1998). Few studies have been performed to directly compare the effect of ploughing depth on the performance of peas. Ploughing to a soil depth of 14–16 cm significantly reduced spring pea grain yields under conventional conditions compared to deep ploughing to a soil depth of 23–25 cm (Baigys et al., 2006). This finding was confirmed by Pranaitis and Marcinkonis (2005), who found an increase in spring pea yield performance with increasing depth of ploughing. To date, no studies have been published to confirm the agronomic utility of shallow ploughing in winter pea cultivation.

The main objectives of this study were to: (a) examine to what extent intercropping winter peas and triticale is beneficial in improving pea winter survival, (b) quantify the effect of shallow ploughing on biomass production, yield performance and grain quality of sole or intercrops of normal-leafed or semi-leafless winter peas and triticale compared to deep ploughing and (c) study the impact of sole or intercropping winter peas of differing leaf type and triticale on the yield performance of a succeeding wheat crop in deep and shallow ploughed soils.

2. Material and methods

2.1. General site and soil characteristics

The field experiments were carried out at the experimental station of the Thünen Institute of Organic Farming at Trenthorst in Northern Germany (53°46′N, 10°30′E, 43 m a.s.l.) in the period 2009–2012. The 30-year (1978–2007) mean annual precipitation at the experimental site is 706 mm with a mean air temperature of 8.8 °C. The soil type was identified as a Stagnic Luvisol and the texture as a loam soil (18% clay, 39% silt and 43% sand) according to the World Reference Base for Soil Resources (WRB). At the start of the experiments in 2009 and 2010, the organic carbon contents were 11.0 and 13.9 g kg^{-1} and the pH averaged 6.9 and 6.5, respectively, at 0–20 cm soil depth. The phosphorus, potassium and magnesium levels were non-limiting to crop production. The preceding crops at the experimental fields were triticale (2009/2010, *Triticosecale* Wittmarck) and oilseed rape (2010/2011, *Brassica napus* L.).

2.2. Experimental design and crop management

The intercropping experiments were conducted in 2009/2010 and 2010/2011 and comprised the factors ploughing depth, winter pea cultivar, and crop stand. For the factor ploughing depth, deep ploughing (DP) was compared with shallow ploughing (SP). Deep ploughing consisted of stubble tillage by a precision cultivator to a soil depth of 8–10 cm and of mouldboard ploughing to 25–27 cm, which is a common tillage system on organic farms in Germany. Two passes with a skim plough (Stoppelhobel, Zobel-Stahlbau, Germany) were performed in the shallow ploughing treatment (stubble tillage: soil depth 4–6 cm, primary tillage: soil depth 10–12 cm). One pass with a precision cultivator and a rotary harrow to a soil depth of 8–10 cm and of 6–8 cm, respectively, were used for secondary tillage in both ploughing treatments. Secondary tillage was undertaken to reduce clod size, level soil surface, and control weeds. Tillage, sowing and harvest dates of the intercropping experiments are presented in Table 1. In the past, experimental fields were ploughed to a soil depth of 25–30 cm.

Two winter pea EU-cultivars with different leaf types and flower colours were tested. E.F.B. 33 (shortened EFB) is a normal-leafed, coloured-flowered winter pea, whereas James is characterised as a semi-leafless type with a white flower colour.

Winter peas were grown as sole crops (EFB SC, James SC, 80 germinable kernels m^{-2}) and as intercrops with triticale (EFB-TR IC, James-TR IC). Triticale was grown as well as a sole crop (TR SC, cv. Grenado) with a projected plant density of 300 plants m^{-2}. The species in the winter pea-triticale intercrops (40 germinable kernels winter pea and 150 germinable kernels triticale m^{-2}) were sown in alternate rows. Sowing was performed with a plot seeder (PZT D3-24 Quatro, Agrar Markt Deppe, Germany). The sowing depth was 4–6 cm with a row spacing of 12.5 cm.

The field experiments were conducted using a split-plot design with four replicates with the ploughing depth as the main plot and the crop stand as the subplot. The plot size was 2.75 × 15 m. The field experiments were managed according to European organic farming standards. Weeds in sole and intercrops were not controlled.

After the harvest of the intercropping experiments, shallow and deep ploughing was performed in the same way as described above for the intercropping experiments and winter wheat cv. Achat was sown. Soil and crop management details for the succeeding crop experiments are listed in Table 1.

Long-term weather data were taken from the nearest National Meteorological Service weather station in Lübeck-Blankensee (53°81′N, 10°71′E). The air temperature and precipitation during the experimental period were recorded near the experimental sites. Snow depth was also measured at the weather station in Lübeck-Blankensee and compared to snow cover observations at the experimental fields.

2.3. Specific weather conditions during the intercropping experiments

2.3.1. Intercropping experiment 2009/2010

November was warmer than the long-term average, whereas the temperatures from December until the end of February were considerably lower than the long-term average (Table 2). Frost days were present during the middle and the end of December and all of January as well as February. The minimum air temperature was −14.6 °C on 26 January. Sufficient snow cover was only present on a few frost and ice days in December. The crop stands were completely covered with snow in January and February. In the first 10 days of March night temperatures were below 0 °C without snow cover, falling to −11.2 °C on 7 March. Only two frost days occurred in April and one in May. Considerable fluctuations between maximum and minimum daily air temperature were present particularly on frost days from March to May. The total number of frost and ice days was 67 and 28, respectively, during the entire winter of 2009/2010. The cold sum of the winter 2009/2010 reached 147. Precipitation differed largely from the long-term average, with the period December to April being drier than normal. However, the rainfall total in May largely exceeded the 30-year average.